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**Mortensen, Niels Gylling**

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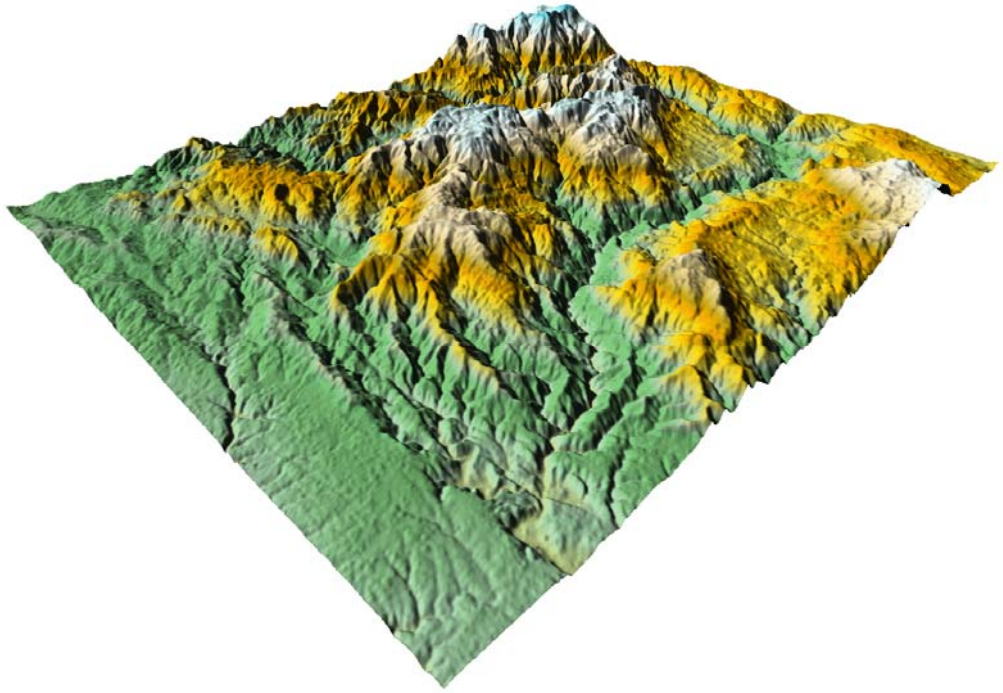
# WAsP prediction errors due to site orography

Niels G. Mortensen
Wind Energy Department
Risø National Laboratory

WAsP Days ’05
24-25 January 2005

# Outline

- Accumulation of orographic prediction errors
- WAsP basics in complex terrain
  - Size of map
  - Contour line interval
  - Spot height elevations
- Wind speed correlations
- Site ruggedness
  - Speed-up ratio
  - Relative relief
  - Std. dev. of elevations
  - Flow separation
    - Site ruggedness index RIX
    - Orographic performance indicator ΔRIX



# Background

- European Wind Atlas, Vol. II: *Measurements and Modelling in Complex Terrain*. Multi-partner EU project from 1990-95.

- Bowen, A.J. and N.G. Mortensen (2004). WAsP prediction errors due to site orography. Risø-R-995(EN). Risø National Laboratory, Roskilde. 65 pp.

- Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. Proc. *1996 European Union Wind Energy Conference*, Göteborg, 584-587.

- Rathmann, O., N.G. Mortensen, L. Landberg and A. Bowen (1996). Assessing the accuracy of WAsP in non-simple terrain. Proc. *8th British Wind Energy Association Conference*, Exeter, 413-418.

- Mortensen, N.G. and E.L. Petersen (1998). Influence of topographical input data on the accuracy of wind flow modelling in complex terrain. Proc. *1997 European Wind Energy Conference*, Dublin, 317-320.

# Accumulation of orographic prediction errors

- Application procedure

  $U_A + (\Delta U_2 + E_2) = U_{Pe}$

- Analysis procedure

  $U_M - (\Delta U_1 + E_1) = U_A$

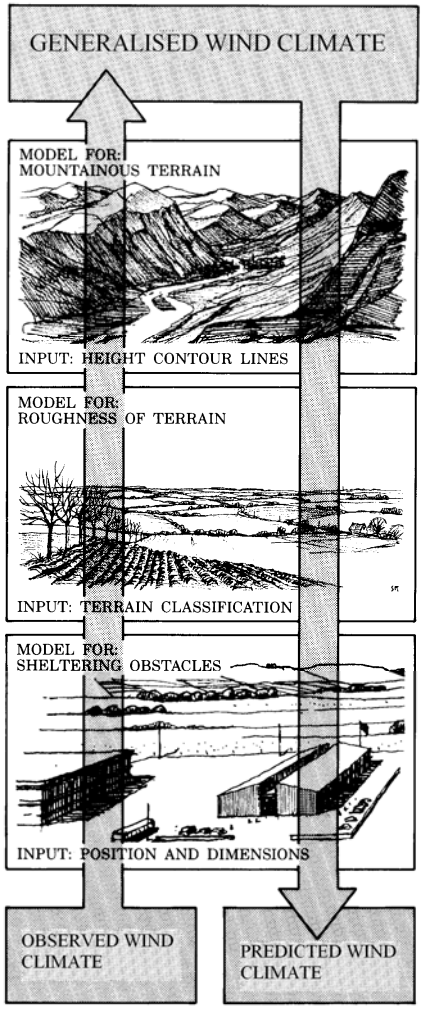
- Combined procedure, eliminating $U_A$

  $(U_M - \Delta U_1 + \Delta U_2) + (E_2 - E_1) = U_{Pe}$

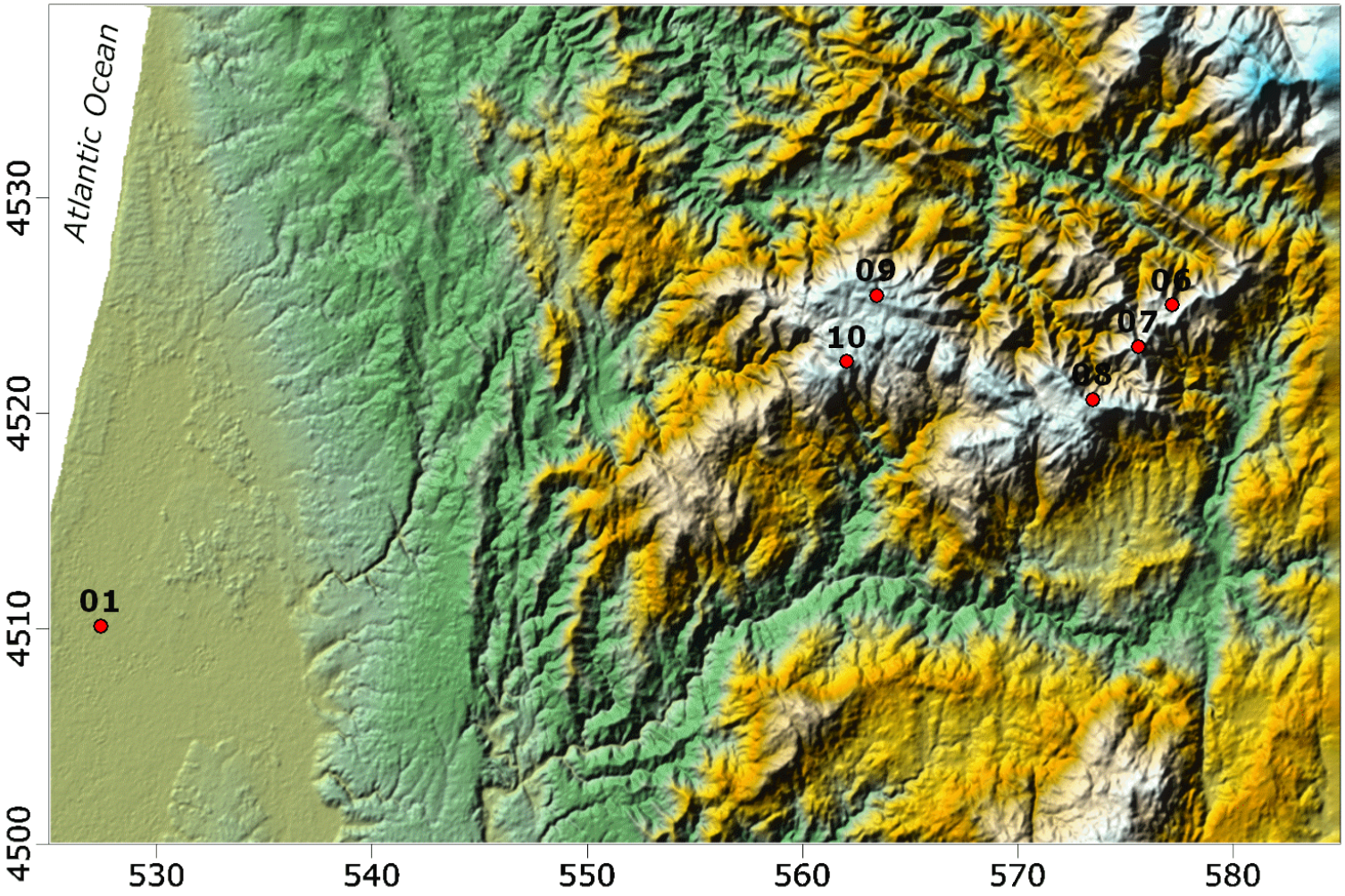
- The correct estimation is then made up of

  $U_{Pm} = U_M - \Delta U_1 + \Delta U_2$ (perfect prediction)

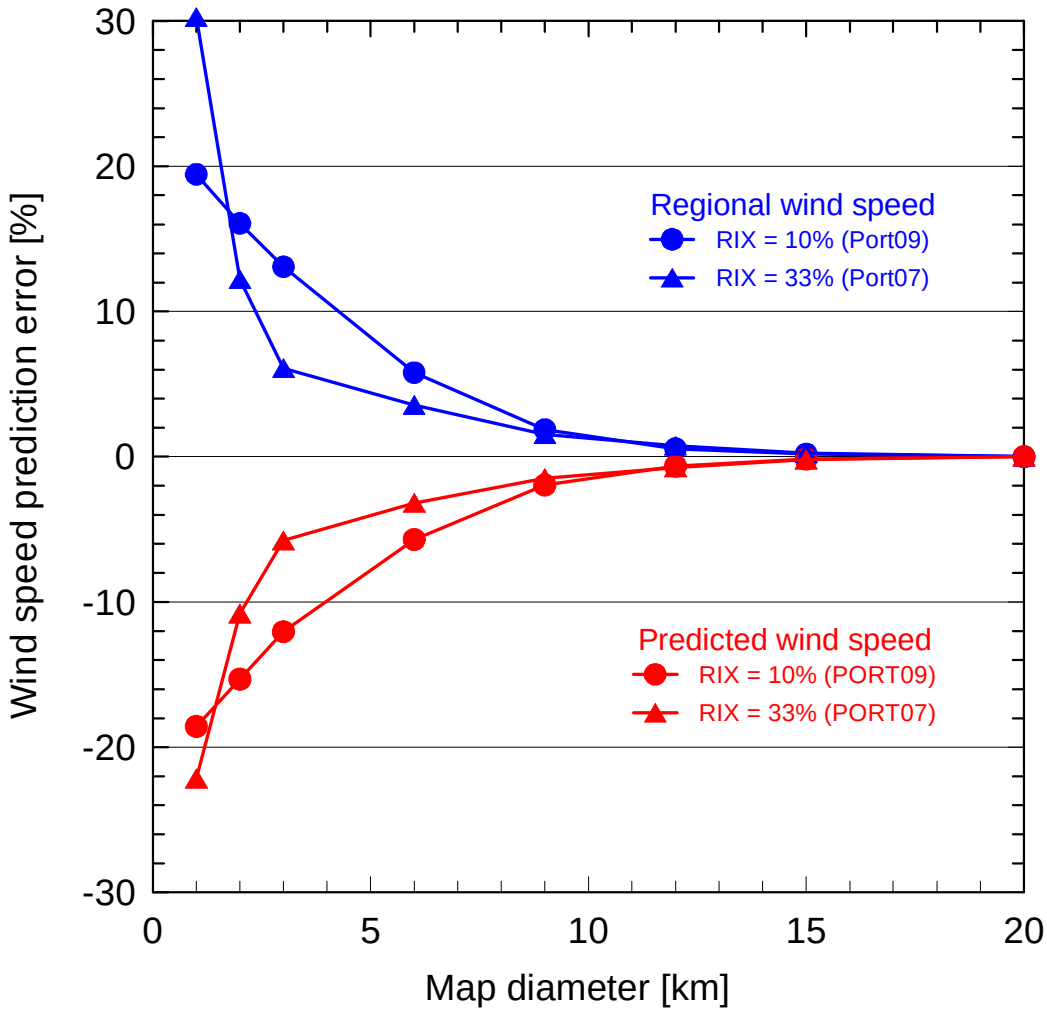
  $U_{Pe} = U_{Pm} + (E_2 - E_1)$ (prediction error!)



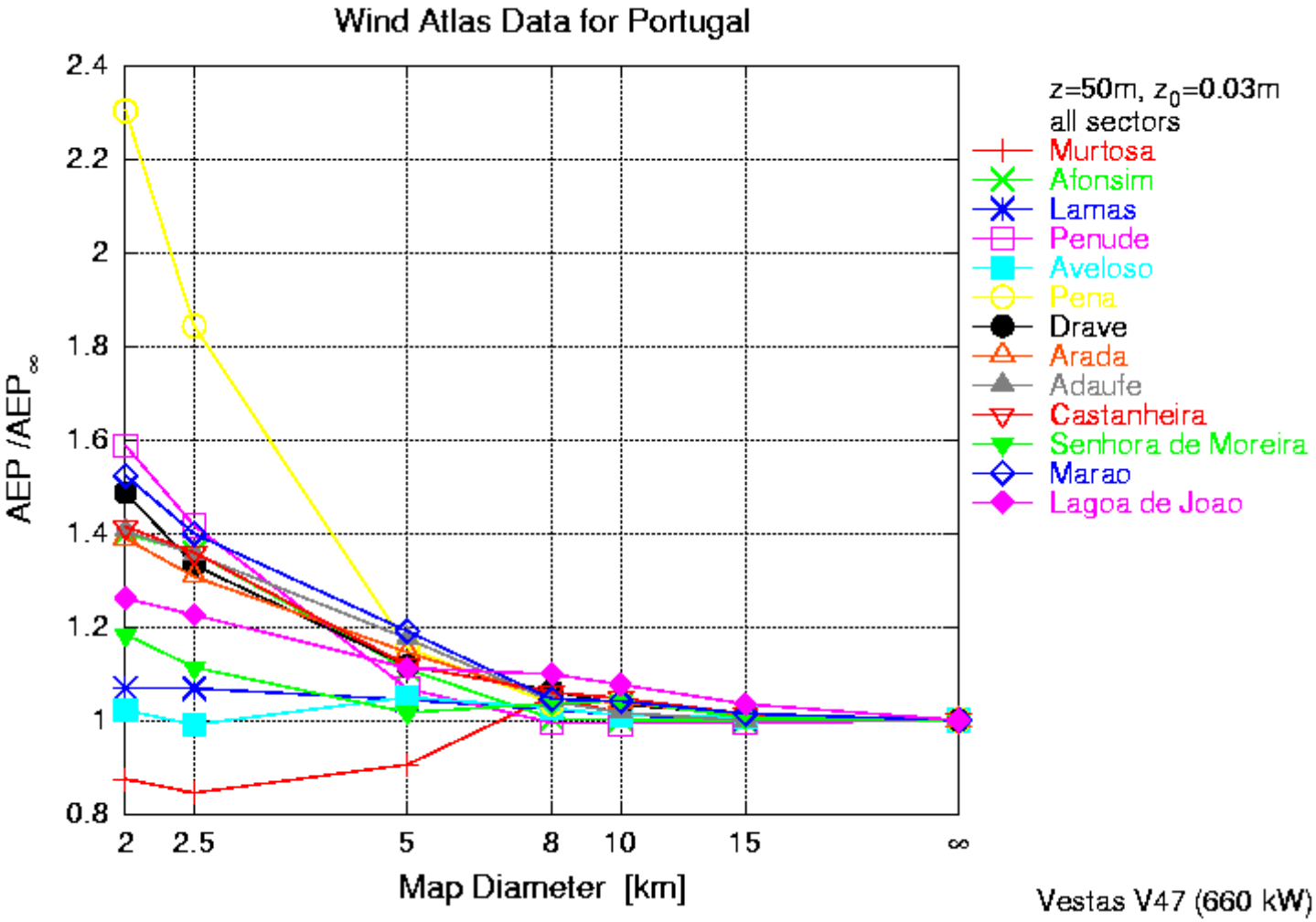
# Case study in northern Portugal



# Modelling errors and map size I



# Modelling errors and map size II



# The similarity principle – revisited

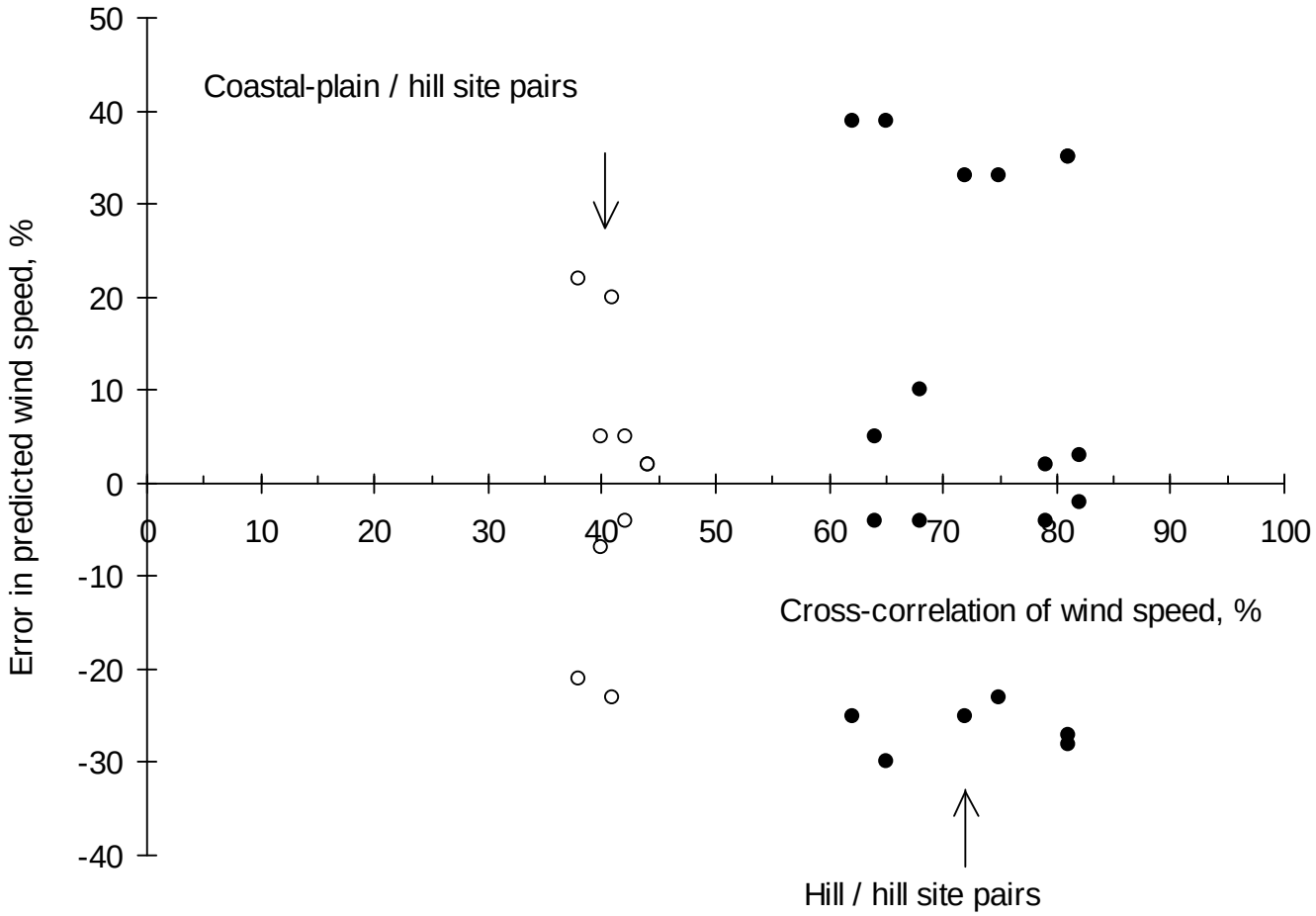
The predictor and the predicted site should be as similar as possible

- Topographical setting
  - Ruggedness index (RIX)
  - Elevation and exposure
  - Distance to significant roughness changes (coastline)
  - Background roughness lengths
- Climatic conditions
  - Same regional wind climate (synoptic and meso-scale)
  - General forcing effects
  - Atmospheric stability

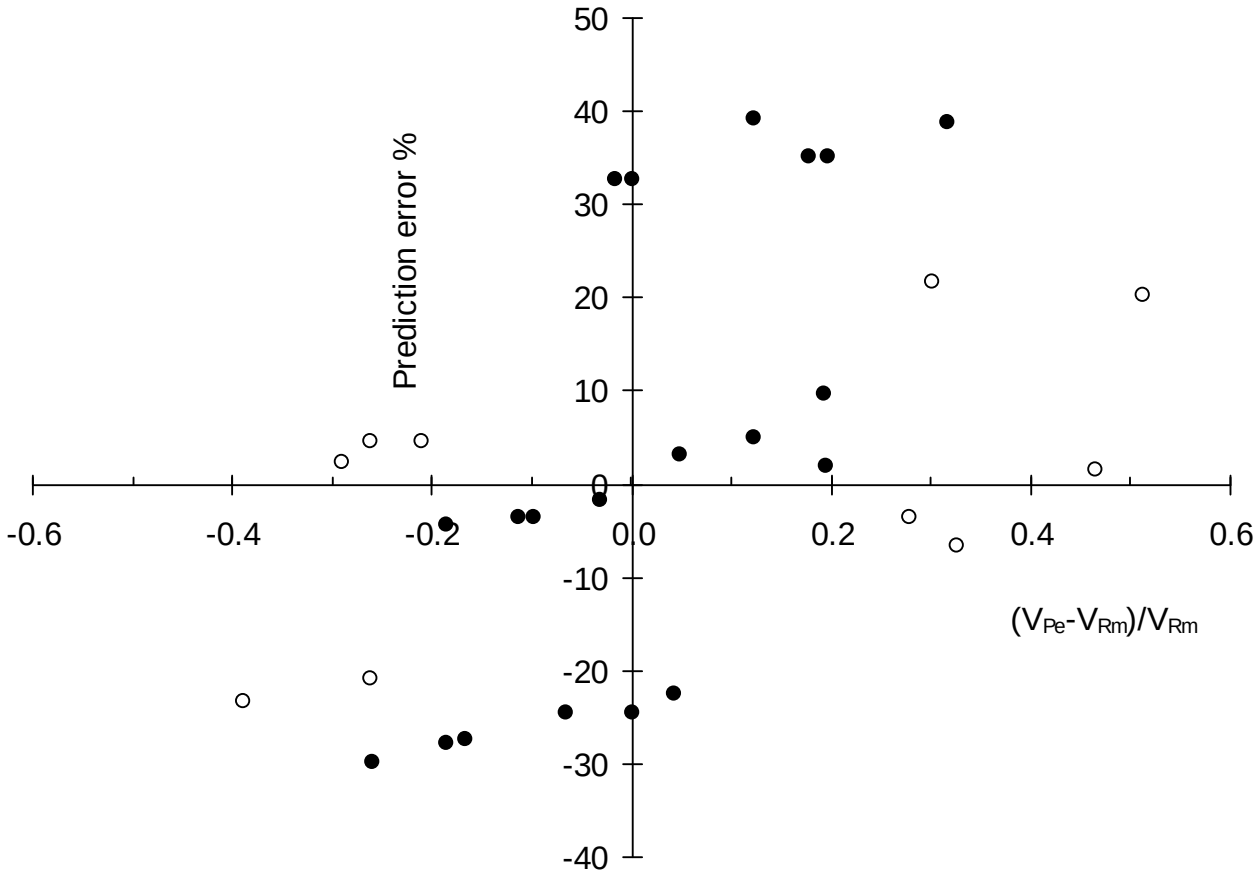
This means that the basic input data should also be similar

- WAsP map
  - Map size
  - Contour interval
  - Accuracy and detail
  - Roughness classification
  - …

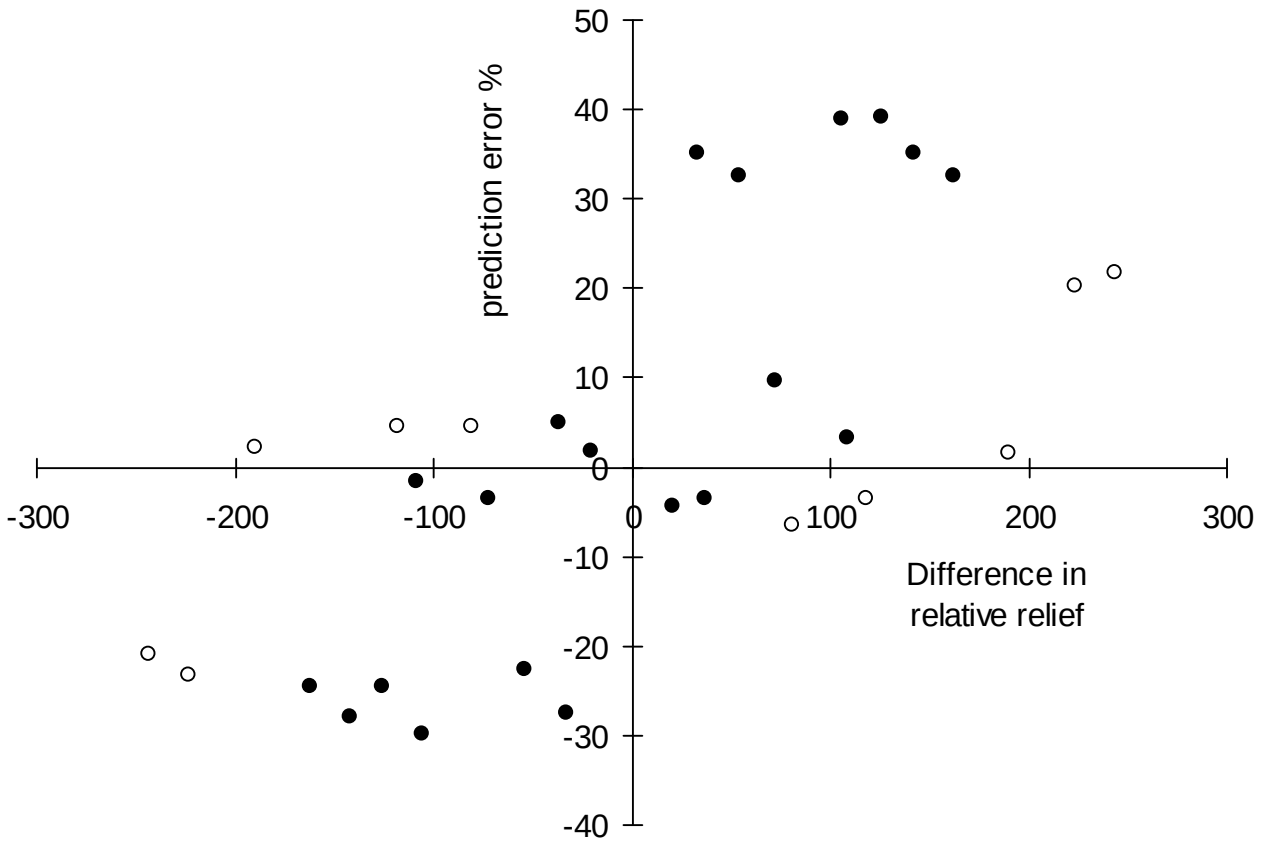
# Cross-correlation of wind speeds



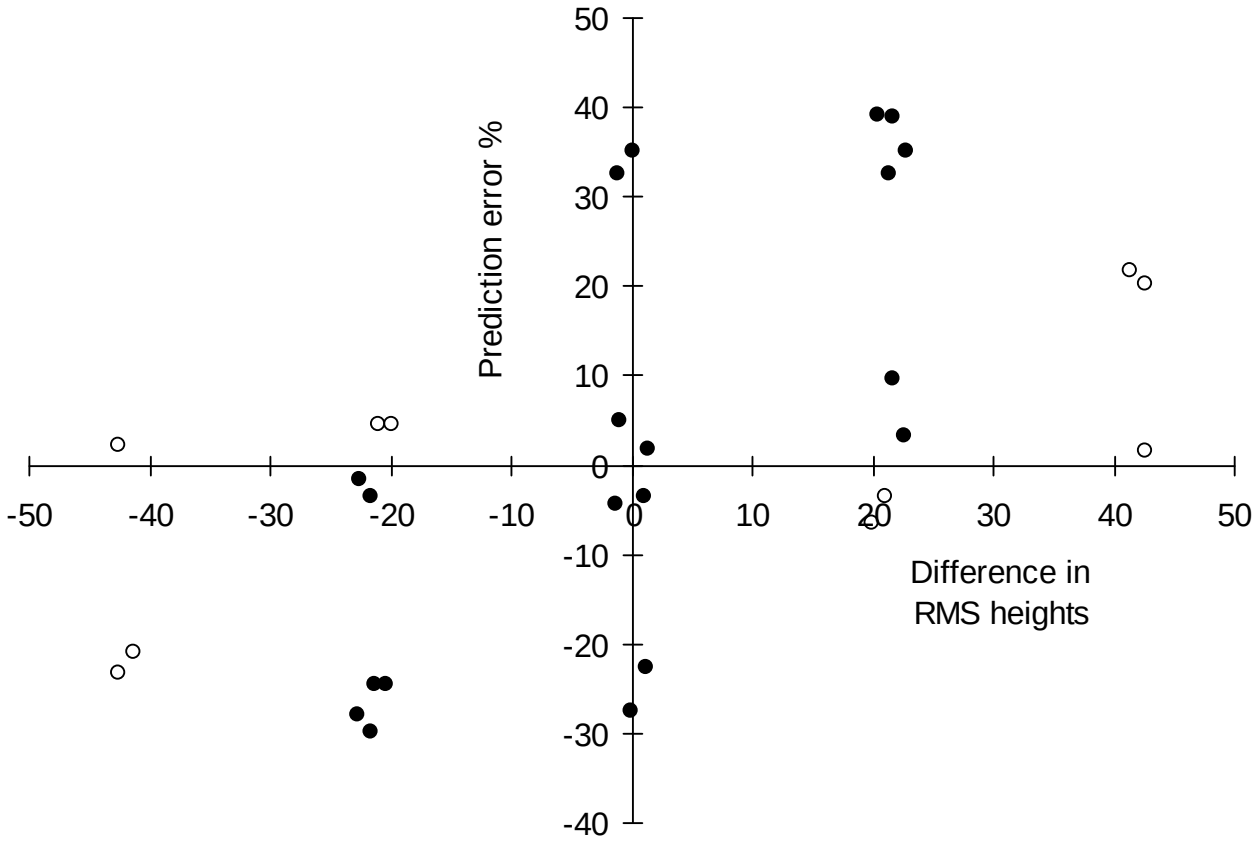
# Prediction error vs. speed-up ratio



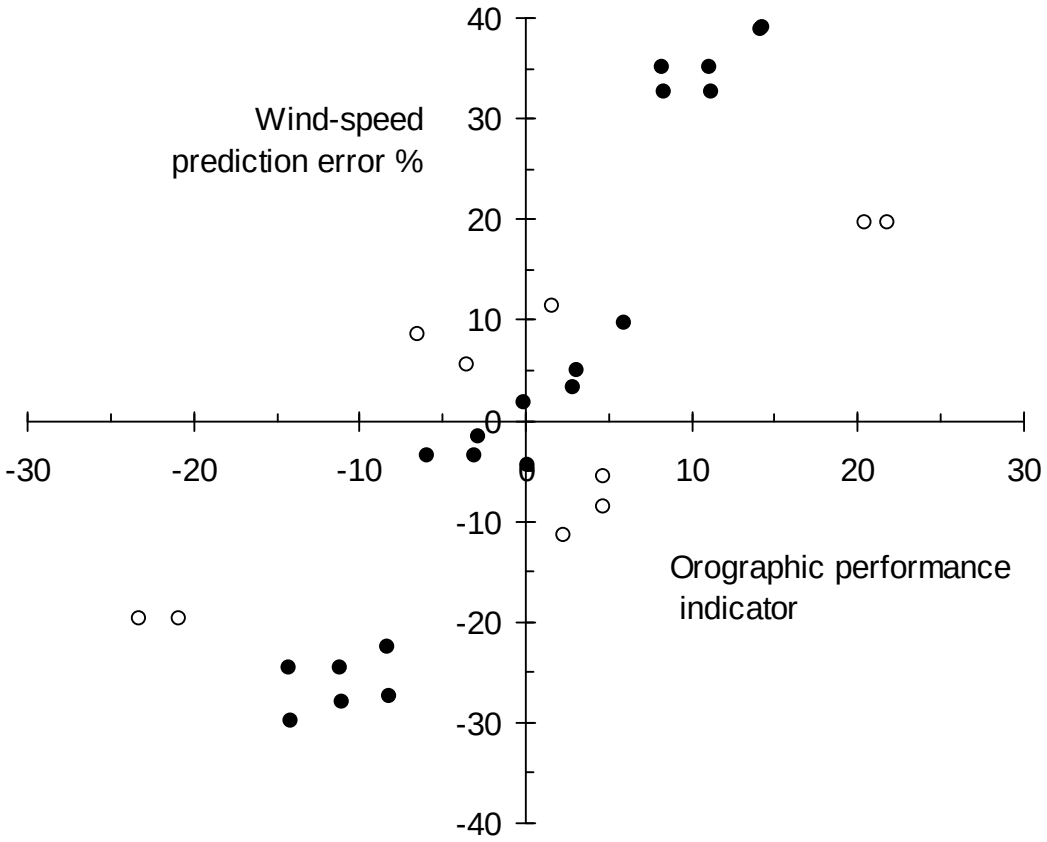
# Prediction error vs. relative relief difference



# Prediction error vs. RMS height difference



# Prediction error vs. RIX difference

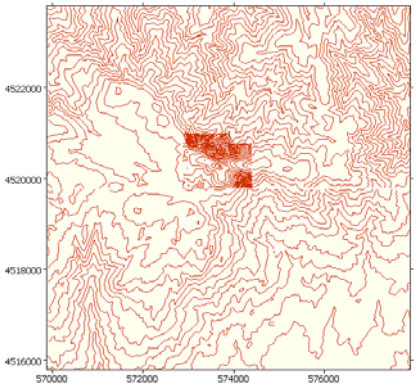


# The Ruggedness Index – revisited

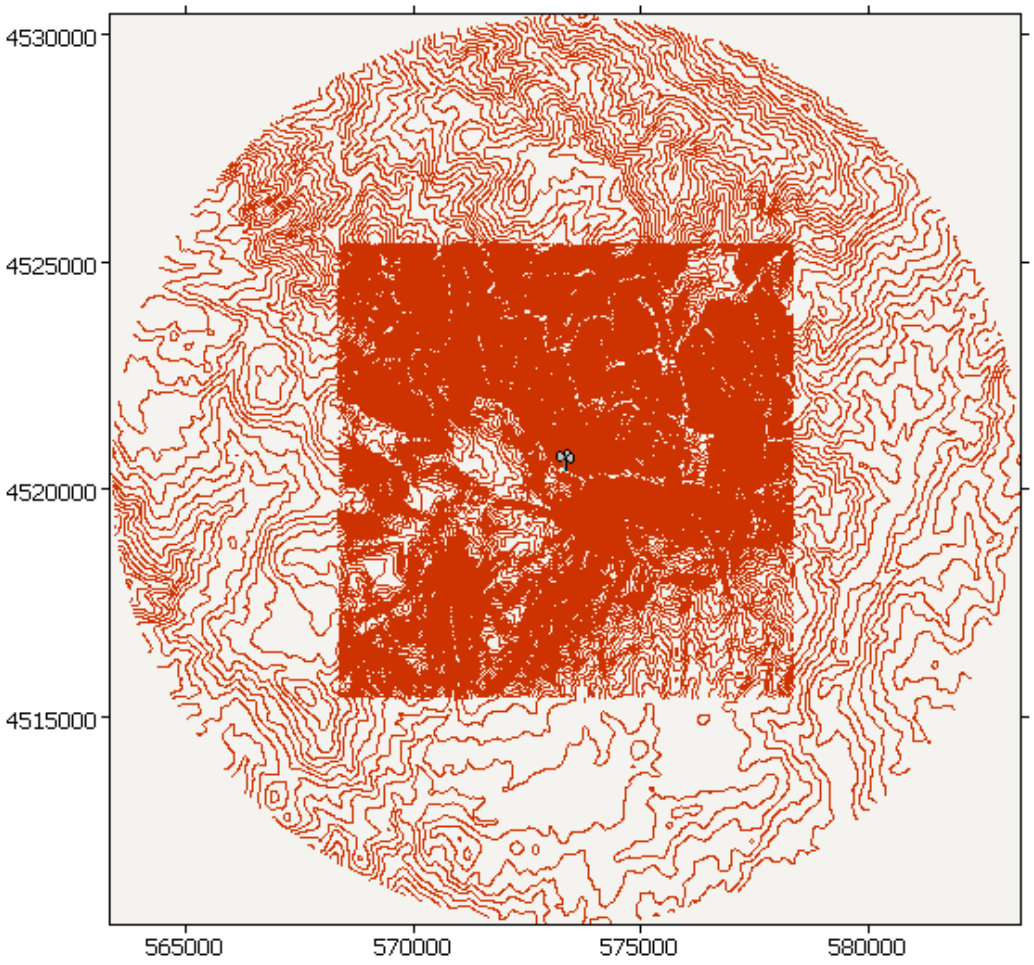
- Reanalyses of the Portuguese data set
  - Larger, more detailed and accurate maps
  - Improved RIX calculation (WAsP or ME)
  - More calculation radii: 72 rather than 12
  - RIX configuration corresponds to BZ-model

- Data analysis and presentation
  - Asymmetry in plot of speed error vs. $\Delta$RIX
    - speed error was defined as $(U_p/U_m - 1)$
    - not obvious which trend line(s) to fit…
  - Substitute $\log(U_p/U_m)$ for $(U_p/U_m - 1)$
  - Easier to fit a trend line…?

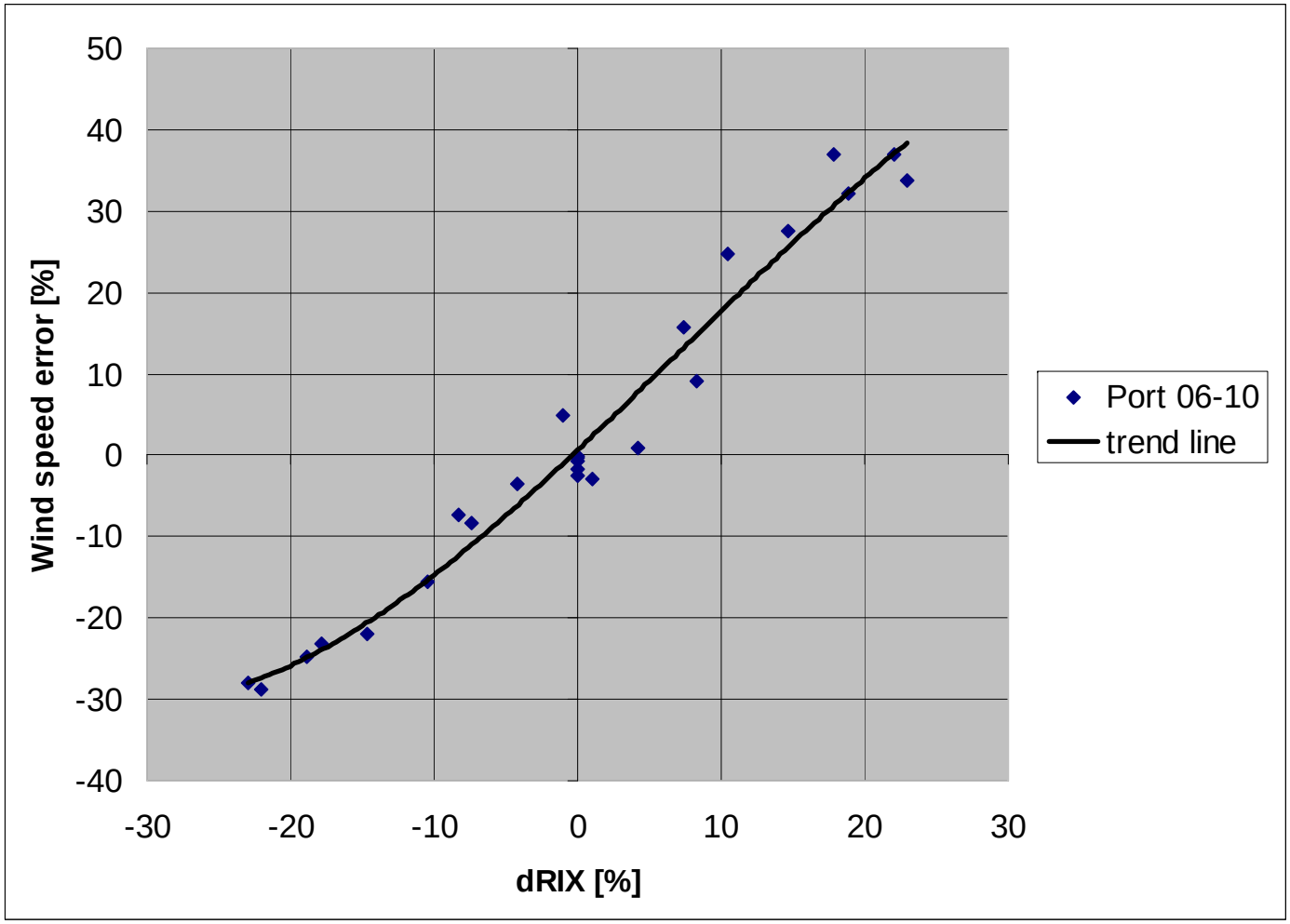
# Maps for RIX calculation and test



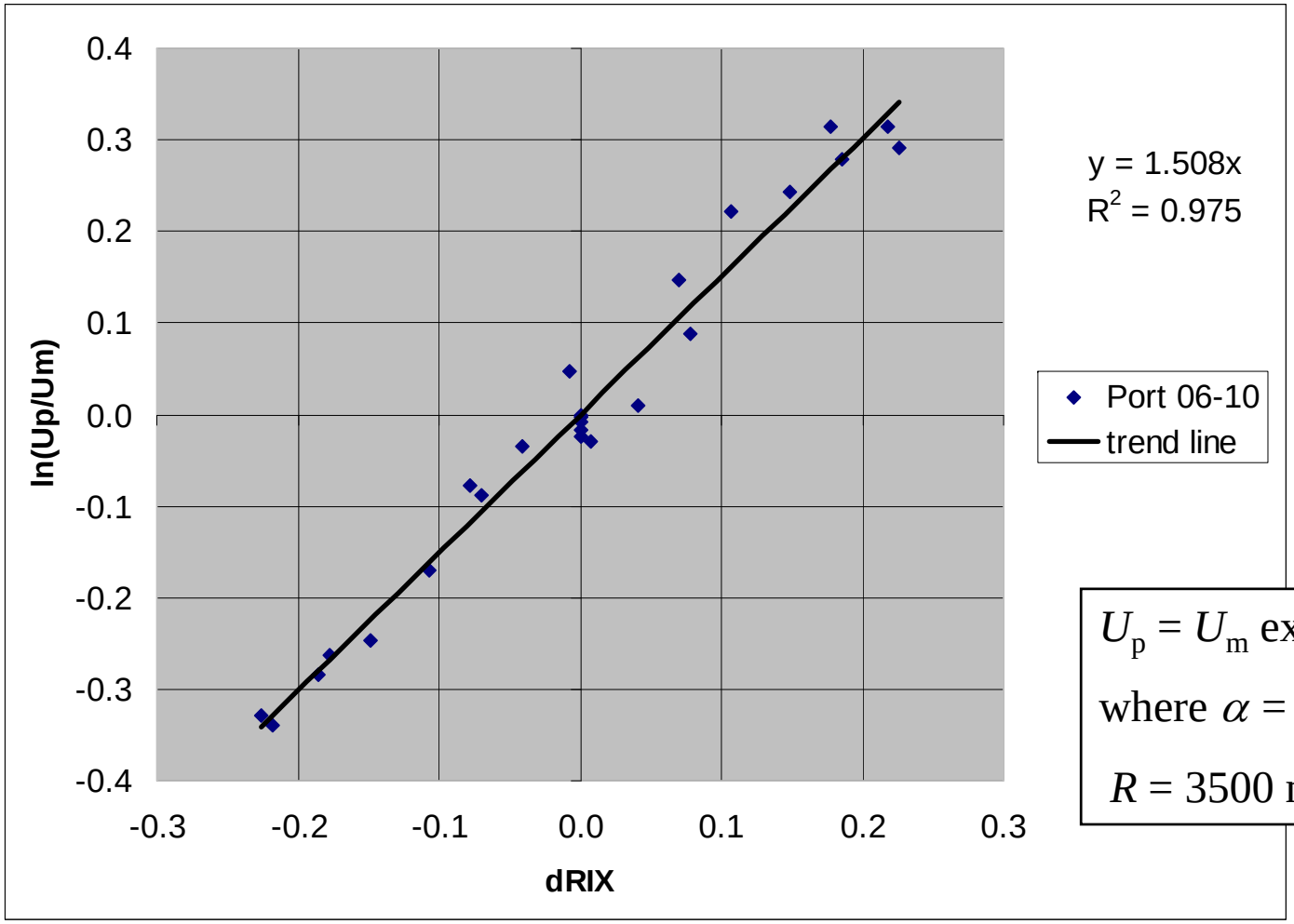

- Hand-digitised map
  - 8 by 8 km$^2$
  - 50- 10-m contours
- SRTM-derived map
  - 20 km radius
  - 50-, 10- and 5-m contours



# Wind speed error vs. ΔRIX (new maps etc.)



# $\log(U_p/U_m)$ vs. $\Delta$RIX




$U_p = U_m \exp(\alpha \Delta\text{RIX})$

where $\alpha = 1.5$

$R = 3500$ m and $\theta_c = 0.3$

# Things to test…

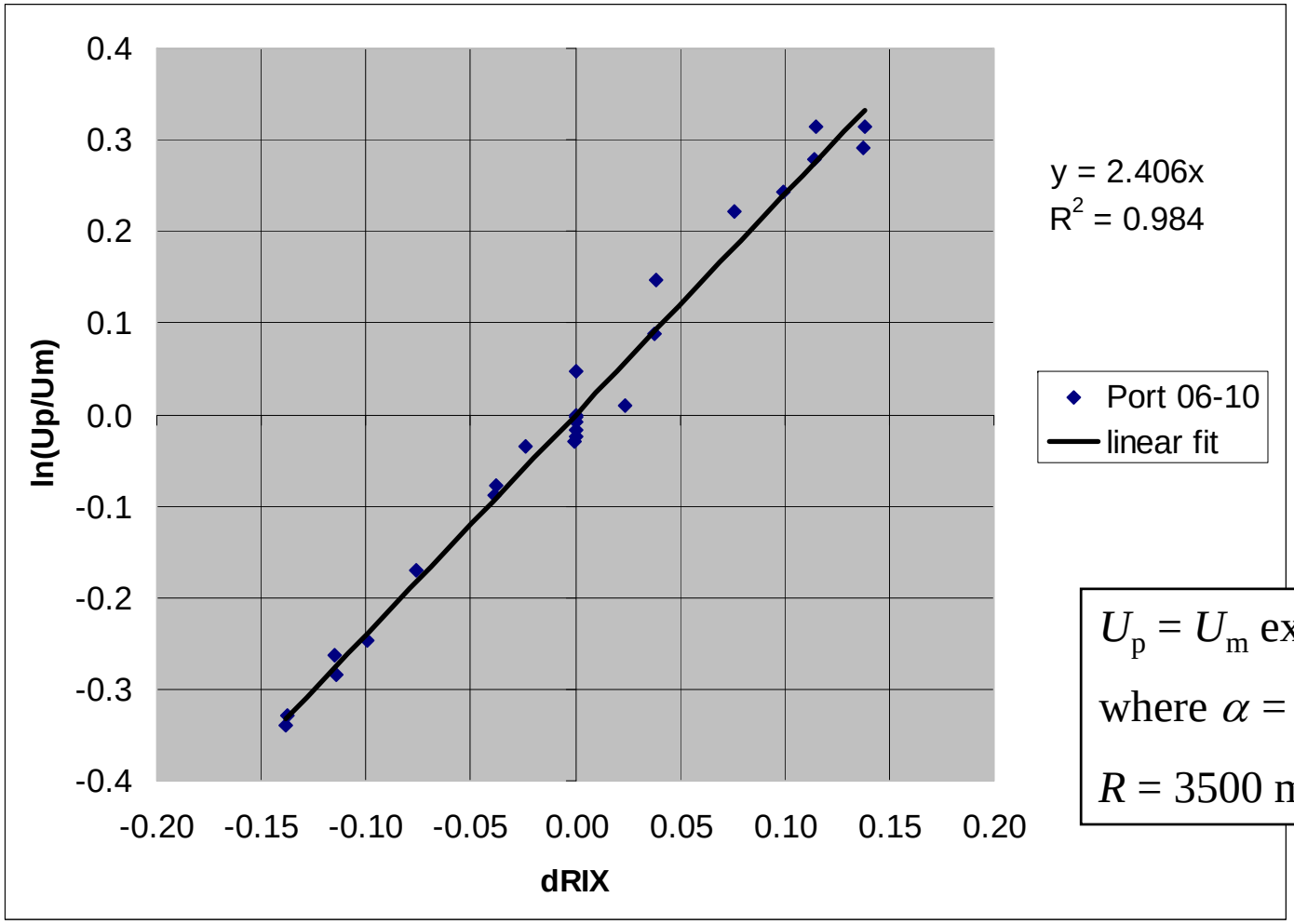
- Wind speed prediction error is (almost) fixed…
  - Number of sectors
  - Modelling parameters
- RIX configuration can be varied easily
  - Original configuration somewhat arbitrary
  - Different calculation radii (3, 3.5, 4, and 5 km)
  - Calculation radius that provides max. RIX?
  - Different critical slopes (0.30, 0.35, 0.40, 0.45)
  - Matrix of $R^2$ for different set-up's
- Weighting RIX with wind rose frequencies

# Influence of RIX radius and critical slope

| Radius $R$ [m] | Critical slope $\theta_c$ | | | |
|---|---|---|---|---|
| | **0.30** | **0.35** | **0.40** | **0.45** |
| **3000** | 0.960 | 0.967 | 0.978 | 0.973 |
| **3500** | 0.972 | 0.974 | 0.984 | 0.986 |
| **4000** | 0.971 | 0.978 | 0.982 | 0.979 |
| **5000** | 0.969 | 0.977 | 0.979 | 0.973 |

$R^2$ for different values of the calculation radius and critical slope.

# Recalculation – best fit values

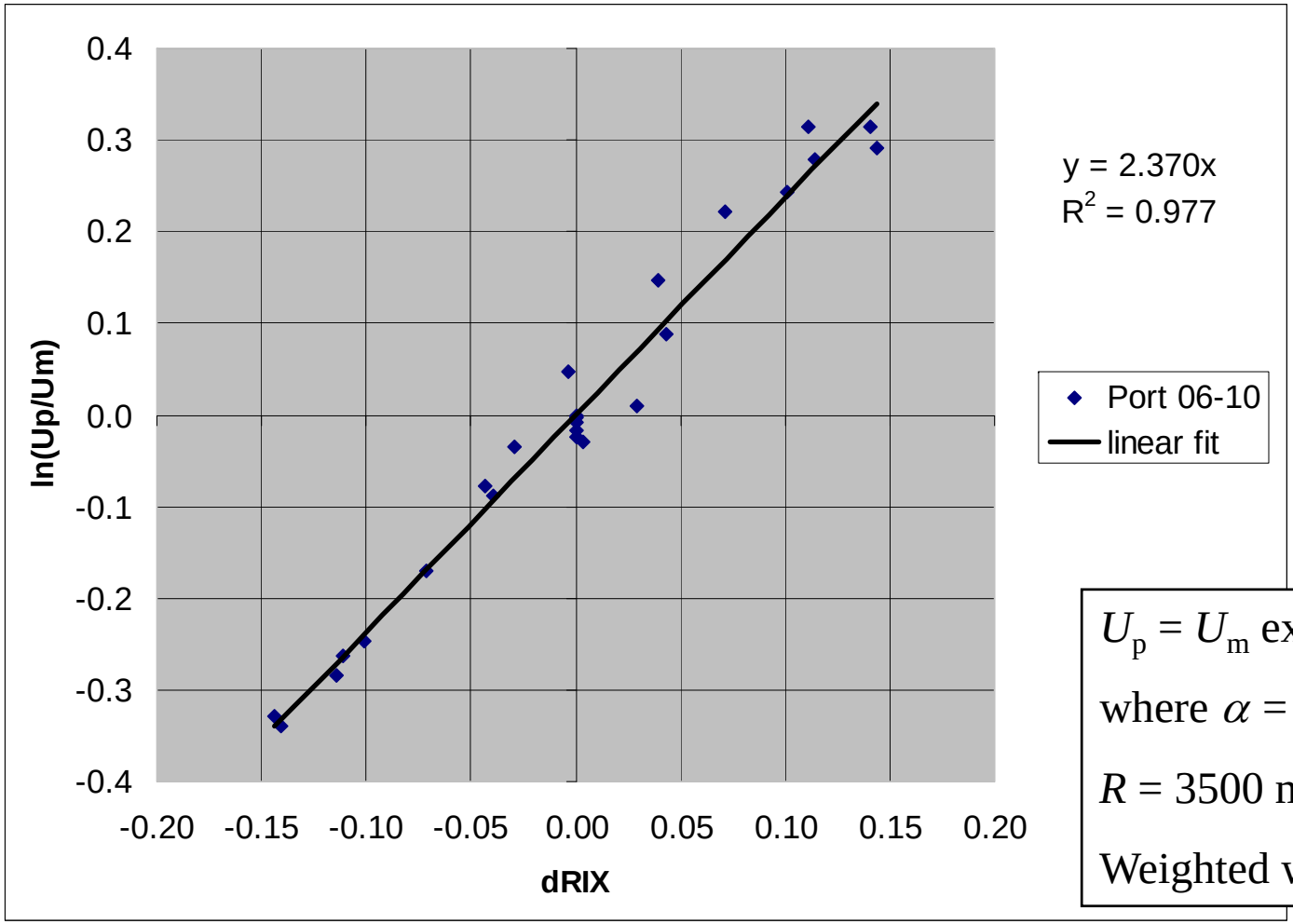



$U_p = U_m \exp(\alpha \Delta \mathrm{RIX})$

where $\alpha = 2.4$

$R = 3500$ m and $\theta_c = 0.4$

# Recalculation – weighted with wind rose




$U_p = U_m \exp(\alpha \Delta \mathrm{RIX})$

where $\alpha = 2.4$

$R = 3500$ m and $\theta_c = 0.4$

Weighted with wind rose

# Conclusions

- The similarity principle
  - WAsP inputs (maps) should also be similar, of course
- Performance indicator $\Delta$RIX
  - Concept reinforced using new and better data
- Relation between wind speed error and $\Delta$RIX
  - Linear relation between $\log(U_p/U_m)$ and $\Delta$RIX
  - Relation not very sensitive to calculation radius $R$
  - Relation not very sensitive to the critical slope $\theta_c$
  - $\Delta$RIX weighted with the wind rose does not improve the relation between $\log(U_p/U_m)$ and $\Delta$RIX